In Vivo Determination Of The Mobile Bearing Total Ankle Prosthesis Kinematics

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Introduction: The present study analyzes the mobile bearing total ankle prosthesis kinematics under in vivo, weight-bearing conditions. The implant 3D range of motion information may help the surgeon assess if the treatment is successful. The relation between rotational and translational components of spatial joint motion also gives the engineers invaluable knowledge to improve future implant designs.

Materials and Methods: Twenty patients (10 female, 10 male) with an implanted talocrural joint (Salto Total Ankle Prosthesis, Tornier, Saint Ismier, France) were studied using a previously reported method based on fluoroscopy [1]. All subjects were judged clinically successful without pain or ligament instability. Two activities were analyzed; gait and step-up. A 3D-to-2D registration technique [2] (Fig. 1) was used to determine the medial and lateral condyle anterior/posterior (A/P) translations, plantar/dorsiflexion, eversion/inversion, internal/external rotations and the spatial rotation about an instantaneous axis of rotation. To present the results in terms of clinical terms easily used by the orthopedic society, the Grood and Suntay [3] joint coordinate system has been employed, as recommended by the International Society of Biomechanics [4].

Results: For both activities, the average results showed that the lateral contact point (the closest point between respective talus component condyle and the tibial component) was more anterior than the medial contact point. Both points showed similar average range of translation (2.0mm and 2.1mm for gait and 2.8mm and 2.9mm for step-up). The translation of medial and lateral contact points is the result of both translational and rotational motion of the talus relative to the tibia. The analysis of pure translation (the distance between centers of tibia and talus implant components) showed that on average the tibia translated anteriorly 1.5mm during gait and 2.3mm during step-up. In the coronal plane the average rotation ranged from 0° to 2.3mm during gait and 2.5mm during step-up. The analysis of the spatial rotation of the implants revealed that on average the tibia translated anteriorly 1.5mm during gait and 2.3mm during step-up. In the coronal plane the average rotation of the talus ranged from 0° to 2.3° during gait and 2.5° for step-up, respectively. During gait, the flexion in the sagittal plane changed almost linearly from 8.1° plantarflexion at heel strike (HS) to 0.4° dorsiflexion at toe off (TO), the average range was 9.2° (Fig. 2). For the step-up activity the pattern was different; tibia rotated from 2.1° plantarflexion at HS, through 1.7° of dorsiflexion at 33% of step-up and returned to 2.0° plantarflexion at TO, the average range was 8.0°. Interestingly, on average for gait the internal rotation from 0.5° to 2.1° was observed, while for step up external rotation from 0.5° to 2.0°. The analysis of the spatial rotation of the implants revealed that the instantaneous axis of rotation was oriented mainly in the medial-lateral direction (Fig. 3). This confirmed that the dorsi-/plantarflexion was the dominating rotation occurring in the ankle joint. The average range of the resultant 3D rotation was 10.3° and 10.2° for gait and step-up, respectively. Although the range of motion was similar for both activities, the pattern was different (Fig 2). These results confirm the differences observed while analyzing pure dorsi-/plantarflexion

Discussion: The results showed that the Salto TAA has sufficient ROM and the average motion pattern was smooth and continuous. It was further observed that the rotations dominated the spatial motion of ankle joint. Even though the analyzed total ankle replacement was mobile bearing, the measured pure translation was small and may persuade the engineers to focus on reproducing the rotational rather than translational portion of the motion of the ankle joint.


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Fig. 1. 3D-to-2D registration technique demonstrated for gait performed by a patient with implanted left ankle.

Fig. 2. Average results of the dorsi-/plantarflexion (left) and of the spatial rotation about instantaneous axis of rotation (right) for gait (top) and step up (bottom).

Fig. 3. Gait (left) and step up (right) activities.